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Microhole Coiled Tubing Drilling

# Final Report - Concept Design/Business Plan

DOE MICROHOLE COILED TUBING DRILLING

## **Final Report**

# **Concept Design/Business Plan**

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## Introduction

*The primary goal of this project is to develop a coiled tubing drilling rig that can safely and efficiently drill microholes – secondary goals are to set the stage for and establish the microhole drilling market in US Land.*

A market analysis was performed on the shallow drilling market within the United States and Canada. The goal of the market analysis was to identify key trends and the current state of the industry. The key item of the market analysis is the lack of a current Microhole market to evaluate. Therefore trends needed to be inferred from current shallow drilling activity. The current drilling activity trends definitely indicate that there is a potential market for coiled tubing drilling in the United States. The market has been well established in Canada and the technology should be easily adaptable to the United States market. In trying to establish a business case for Microhole drilling it became apparent that a Microhole Coiled Tubing Drilling Rig would need to be capable of performing other operations to keep utilization high enough keep the cost per job down until the Microhole Market can be better established.

An operational study was performed to evaluate the operation of coiled tubing drilling rigs and to better understand all the parameters that might have a bearing on the design and efficiency of a Microhole Coiled Tubing Drilling Rig (MCTR). The information gathered in the operational study was used to evaluate existing coiled tubing drilling rigs. During the evaluation we looked at different efficiency features and the ability of the equipment to perform the desired task within our scope of work. Many of the existing coiled tubing drilling units are very efficient and perform well in the area in which they operate. The major obstacle that we found is that the majority of the units are overweight or over dimension for use in the United States. This made the selection of a unit to evaluate at our Rosharon test site difficult as any unit selected to be modified would not meet the requirements of being DOT road legal.

Difficulty identifying a coiled tubing drilling unit that meets the requirements of a highly mobile coiled tubing drilling rig within the US prompted us to look into the possibility of building a complete package that is more suited to purpose and has a better chance to meet the long term goals of the DOE MCTR project. One of the bases of our design was to have a coiled tubing unit that is scalable to meet the needs of the Microhole market as it develops, while the other key focus was to insure that we were able to incorporate the key features outlined in the scope of work for this project (Lubricator and Tool deployment system, Process and Data Acquisition and Safety/Efficiency Improvements).

This document will outline the overall concept and how we intend to address the issue related to developing a small, highly mobile and cost effective coiled tubing drilling rig. We will discuss the overall equipment layout and what it brings in the way of efficiency, mobility and scalability. This will be followed by the detailed information on how we intend to integrate the key features outlined in the scope of the project.

Finally a business plan will be presented that outlines how we believe the changes and features can help stimulate the growth of a Microhole drilling market. The business plan will attempt to tie in the importance of the other technologies being developed under the Microhole Initiative with the conceptual coiled tubing drilling unit.

## Concept Development

*This chapter has been designed to help explain the process used to develop our conceptual design.*

As mentioned earlier the initial plan was to bring in an existing coiled tubing drilling rig and evaluate its performance and make recommended changes to the unit. We looked at three built for purpose coiled tubing drilling units. The rigs that we evaluated were very well thought out rigs and appeared to be very efficient in there operation.

For this project we evaluated the use of Heartland Rigs MOXIE 2000 and Foremost's Ultra Single and Explorer. All of these units had much to offer but were still larger and heavier than what we would like for a highly mobile rig. We were also concerned with the ease in which we would be able to adapt the changes to the existing units and be able to build future units. For a business case it was very important that we are able to grow the fleet without major obstacles or cost growth.

We therefore examined the possibility of developing a rig from scratch that would encompass all of the design features we are interested in. These design features were based on the original Microhole proposal and the ability to establish and maintain a market. The following is a list of the key features used for the bases of our decision.

- Cost – Unit cost should be comparable to what is readily available on the market today with desired modifications.
- Weight and Dimensions – The unit must be capable of obtaining an annual over weight or over dimension permit for most states of operation.
- Rotary Drilling – The unit needs to be capable of rotary drilling

- Completion Size – Ability to drill and complete up to 4 ½” casing
- Integrated systems – Components need to be integrated such that minimal personnel are required for rig-up and operation
- Automation – Coiled Tubing and Pipe handling operations need to be automated and centrally located to reduce required personnel
- Data Acquisition – Incorporate the ability to record drilling parameters along with coiled tubing parameters
- Casing Handling – Rig needs to be able to run a minimum of range 2 casing efficiently
- Underbalanced Deployment System – Ability to deploy long tool strings underbalance.
- BOP Stack – Ability to handle complete BOP stack for desired operations
- Safety Improvements
  - Egress from drill floor
  - Gas detection and Alarms
  - Kick detection and Alarms
  - Ease of maintaining injector head
  - Working at heights
  - Noise Reduction
  - Elimination of tripping hazards
  - Elimination of common hand traps

The first step of the process was to break apart conventional coiled tubing drilling units into their major components and assign weights and dimensions to these items. These weights and dimensions were then used to evaluate different layout scenarios. The first scenarios examined were single unit configurations. These configurations proved to be extremely heavy when the BOP stack was incorporated onto the unit. Therefore two-piece units were investigated where the equipment was divided between two separate trucks. It was again difficult to reduce the weight significantly because of the additional

weight added by the added truck and trailer. We did manage to identify possible solutions in a two truck configurations but they lost efficiency in the process. The loss of efficiency can be attributed to the elimination of structures that allowed equipment to travel assembled. It was decided that we could not afford the loss in efficiency and looked for a way to maintain the efficiency without adding onto the overall location size.

A time breakdown matrix was used to analyze the effect different unit configurations had on the overall rig-up time. From this analysis we could make assumptions on how best to divide up the unit and not sacrifice efficiency. These assumptions were then placed back into our weight analysis spreadsheet to determine the end net effect.

Once we narrowed down the options we reviewed the options by going through the rig-up procedure with each option. The options were evaluated on their ability to meet the operational specifications and the design risk associated.

Once we had a concept we evaluated it against the theme of the Microhole Coiled Tubing Rig project. First and foremost, can it perform the work necessary and secondly, what advantages does it bring? We found that the new concept maintained all of the original concept goals, but also brought more value to the table than we initially anticipated. The packaging of the new concept allows the unit to be easily scaled to fit the size and type of drilling operation performed. This will be covered in more detail in the next chapter.

### **Conclusion:**

The initial scope of the project has grown as a means to provide the best possible solution and provide the best chance of realizing the end goal of the project, which is to cost effectively drill microhole wells with coiled tubing.

The design of the unit meets our initial goals and brings added value to the project with greater flexibility.

## Concept

*This chapter will focus on describing the concept and its operation. The emphasis is on the concept as the exact operational details will be generated in the design process.*

The concept for the microhole coiled tubing drilling rig (MCTR) has evolved into a three-piece unit that is divided into the following trucks.

- Mast Unit – The mast unit houses the drilling mast and catwalk trailer
- Drill Floor – The drill floor unit houses the drilling BOP, drill floor and control cabin
- Coiled Tubing Unit – The coiled tubing unit is a stand alone unit designed to easily mate with the drill floor

### **Mast Unit:**

The mast unit is designed to handle rotary drilling functions and casing operations. The rotary functions will be performed with either a top drive or rotary swivel. These items will not normally travel on the unit but will be brought out as needed. This is one way that we are able to reduce cost and overall weight of the unit.

The mast unit will have the catwalk integrated into the trailer with a V-door ramp designed to mate with the drill floor. The catwalk will have an automated skate system and rockers for ease of raising casing to the drill floor. The controls for the catwalk will be located within the drillers cabin and will be operated by the driller. Another feature of the catwalk is that it will have two pipe racks one on each side of the catwalk trailer. One pipe rack will be designated for casing while the other will be designated for the BHA assembly.

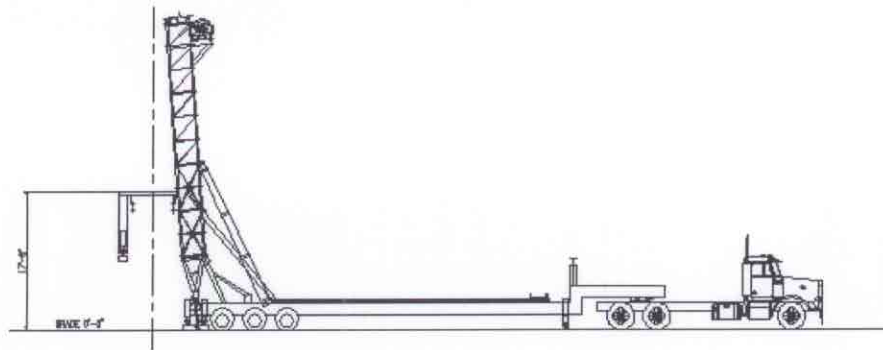


Figure 1: Drilling Mast Unit

Figure 1 shows the general layout of the drilling mast unit. The mast is a telescoping two column mast that will have a clear height above the floor of approximately 74 ft. The mast will be designed to cantilever over well center and allow casing to be pulled through the mast onto the drill floor. The mast will be rated to 140,000 lbf and will be equipped with a four line block and winch. Hydraulic power for this unit will be supplied by the coiled tubing unit allowing the tractor to be disconnected if needed. This unit will be designed to be electric over hydraulic, which will allow the unit to be operated by any hydraulic source with sufficient output.

A power swivel or a top drive system can be mounted in the mast for rotary drilling applications. This will be performed by supporting the power swivel or top drive in the blocks and installing a torque bar or cable into the derrick. The torque bar or cable would then be anchored to the drill floor.

#### **Drill Floor/Cabin Truck:**

The drill floor will be designed to hold a 11" 5,000 psi drilling BOP stack, which contains a flow cross, combi BOP, annular preventor and a bell nipple that is adapted for lubricator attachment. The actual connection type for the lubricator is yet to be determined. During transport the BOP will be pulled over the rear drive axles on a trolley system that also acts as a means to remove the drilling BOP stack between completions for the installation of the next casing hanger. The travel height of the drill floor will be 13' 6" with an installed height of 17' 6". The extra height of the drill floor will be accomplished by jacking the truck up 4' by the use of hydraulic cylinders mounted inside steel legs. Once at the work height the legs will be pinned off for safety. Jacking the floor will allow enough room under the floor to remove the BOP

with up to three casing hangers installed and sufficient room to work over wellheads for re-drill applications.

The drill floor will contain tools for torquing the BHA or casing strings. Along with the tools the floor will be equipped with an API slip bowl for running casing. A separate slip bowl arrangement will be used for handling the BHA.

The drilling cabin will be incorporated onto the drill floor as this is the logical positioning for complete visualization of all operations. The cabin will house the controls for the coiled tubing unit, derrick, catwalk and mud system. The operation of the controls will be discussed separately.

The drilling cabin will be large enough to house five personnel and will be equipped with an exit on either side of the cabin to the ground leading away from the rig. Further design needs to be performed to determine the exact layout and size of the cabin. However, space will be allocated for the coiled tubing operator/driller and a directional driller.

The stairs and walkways will ride on a track system that will allow them to be easily assembled on location. Once the stairs and walkways are positioned the cabin can be jacked up into position with hydraulic cylinders. Manual locks will be used to support the cabin once raised in the event of hydraulic cylinder failure.

A BOP accumulator system will be mounted below the stairs. This will allow the BOP and BOP controls to remain plumbed during transport. The controls of the BOP will be integrated into the drilling control system and a remote panel will be used for operation outside of the cabin.

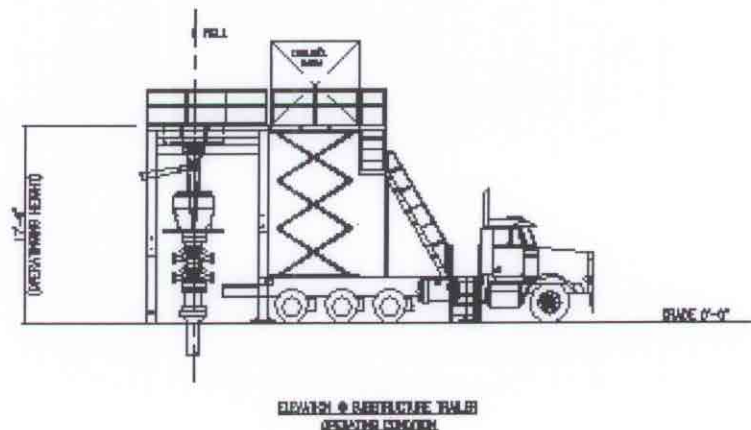


Figure 2 – Drill Floor

### **Coiled Tubing Unit:**

The coiled tubing unit will be a standalone unit that is controllable from the drillers cabin during drilling operations. During standard coiled tubing operations the coiled tubing unit will be controlled from the sleeper birth of the tractor, which will be converted to house the coiled tubing console. To reduce the cost of multiple control systems the control console can be removed from the coiled tubing console and can be placed directly into the drillers cabin. A single wire connection from the coiled tubing unit to the drillers console is all that will be needed to operate the entire coiled tubing unit.

The coiled tubing reel will be a drop in drum style reel that uses the frame rails to directly support the reel drive system. A drip pan will be incorporated into the trailer to catch fluid as it comes off the pipe. The reel will also be equipped with a corrosion inhibitor system to prevent pipe corrosion during storage. A pipe pigging system will also be incorporated to remove water from the reel prior to transport. This will insure that water in the reel does not cause the truck to be over weight.

The trailer will be designed to accept an oversized drum for deeper drilling applications, however the standard drum will hold at least 7,000 ft of 2-5/8" coiled tubing. When the larger drum is installed the unit will need to be over weight and over dimension permitted. With the standard drum the unit will only need to obtain an over weight permit.

A mast mounted on a trolley system will be used to deploy the injector over the well. In transport mode the mast will straddle the reel and the injector will ride at the base of the mast with the BOP installed. This will allow the injector to transport at road legal height with the pipe stabbed. Once on location the mast is raised to vertical and the mast trolley system scopes out 3' – 4' to get the injector over the well. Keeping the mast vertical makes it easier to get the injector on and off the well during tool swaps.

The injector will be supported on a carriage that is equipped with 6" of side shift left or right and will have a hydraulic cylinder that will adjust injector tilt for un-level ground. The carriage will travel up and down the mast hydraulically; the actual method is yet to be decided. The injector at its upper most position will place the coiled tubing BOP approximately 22' above the ground.

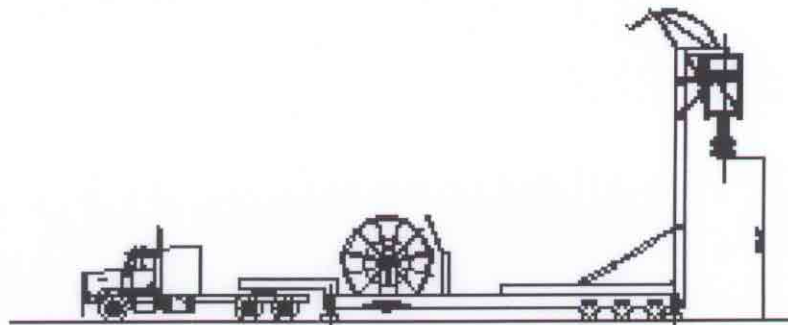


Figure 3 – Coiled tubing Unit

#### **Site Layout and Assembly:**

The first unit to pull onto location will be the drill floor/cabin truck. This truck will center the drill floor over the well and then jack itself up to operational height. Once at operational height the BOP stack can be scoped forward and placed onto the conductor or surface casing head.

Once the drill floor is properly aligned and spotted the mast truck is brought in and positioned in respect to the drill floor. Then the mast can then be raised, which raises the v-door ramp automatically to meet the drill floor. Pipe racks are unfolded from the sides of the trailer for handling casing and BHA components.

The coiled tubing unit is then brought in and is positioned opposite the mast trailer. The coiled tubing unit raises the injector and scopes the injector out to meet the drill floor and align the injector over well center. The injector can be scoped in and out to move off of well center for casing operations.

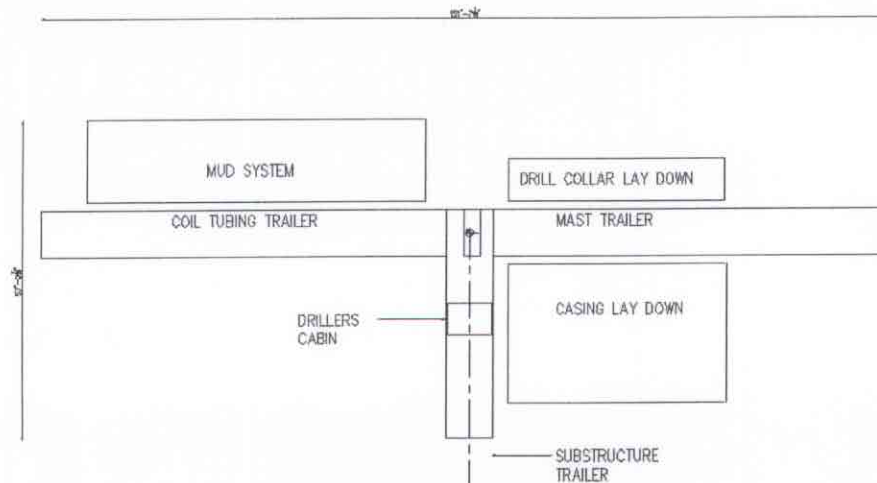


Figure 4 – Site layout

### Tool Deployment:

Underbalanced tool deployment will be handled by slickline deployment methods. Slickline deployment uses wireline to lower the BHA into the well by the means of a lubricator section mounted on top of the BOP stack. Pressure is contained by the use of a slickline grease head. Once the BHA is lowered into the well the pipe and slip rams of the BOP are closed on a deployment bar located on the up hole end of the BHA. Pressure is then bled off of the lubricator section and the lubricator is removed to load the next section of BHA or to allow the injector head to connect to the BHA installed into the well.

A slick line drum can be mounted on the coiled tubing unit to prevent the need for a separate slickline truck from coming out just to deploy tools.

Figure 6 below shows the general arrangement of a slickline deployment stack. The lubricator section for our operation will be capable of deploying 35 ft sections into the well. This will allow a typical wired horizontal BHA assembly to be deployed in two 35 ft sections. A non-wired horizontal BHA may need to be deployed in three sections depending on the motor selection.

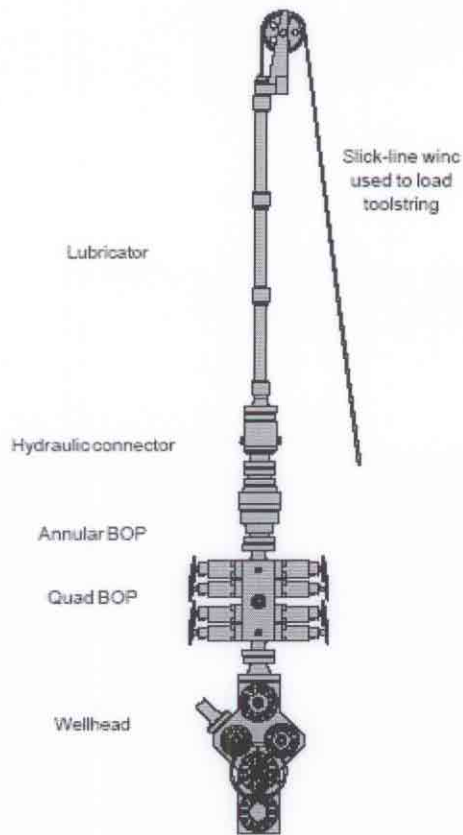


Figure 6 – Slickline Deployment

Loading the BHA into the lubricator section can be accomplished by installing the BHA horizontally on the catwalk trailer. Once the BHA is installed the slick line is connected to the BHA and the grease head is connected to the lubricator. The lubricator is then pushed up the v-door ramp and captured by the rig elevators. The rig elevator and block assembly then pulls the lubricator into the derrick and over the deployment BOP stack. The lubricator is then connected to the BOP stack and the rig block supports the top of the lubricator. For each additional BHA section the lubricator is lowered back onto the catwalk to be loaded.

Figure 7 illustrates the different configurations of the BOP stack for several different types of operation.

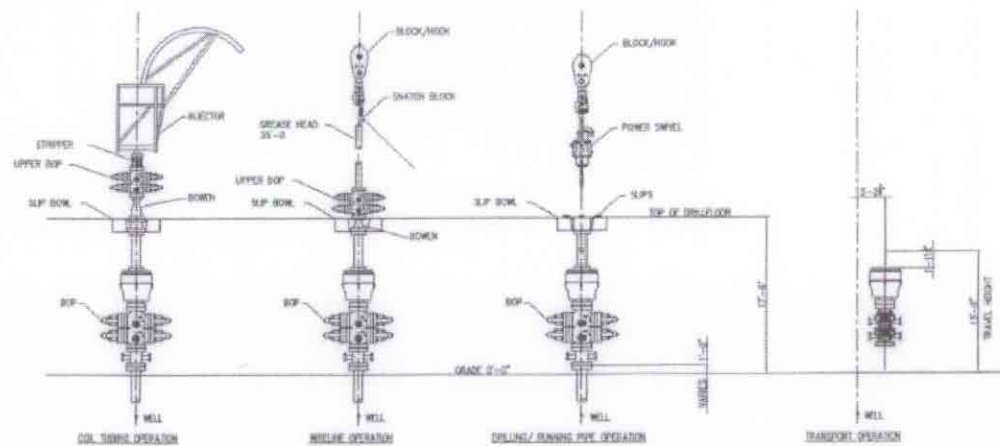


Figure 7 – BOP stack and deployment arrangement

### Control System and Data Acquisition:

The control system for the coiled tubing drilling rig will be an electric over hydraulic system. By using an electric over hydraulic system we can reduce the number of hydraulic connections that need to be made up prior to operation and more functions can be automated to reduce human error.

We have elected to use OpsCab\* an in-house electric over hydraulic control system for coiled tubing units. The reason for selecting OpsCab\* is the ease of installation and its compatibility with our current data acquisition and design software (CCAT 7.0). A list of the OpsCab\* automated functions is listed below. The actual controls can be seen in figure 8.

- Fly-by-wire - no hydraulic connections to operators console
- Sealed (IP65) control console
- Injector speed control - cruise control
- Injector slip control
- Automatic and configurable pull tests
- Automatic injector stop on over pull and snub
- Skate & stripper pressure leakage detection and circuit isolation
- Automatic reel tension adjustment (different RIH and POOH settings)
- Automatic reel brake release and set
- Automatic tubing lubrication at the reel and stripper

- BOP valve position monitoring
- Power pack pump efficiency monitoring
- Automatic pump management (supply on demand)
- Hydraulic injector creep mode
- Automatic injector and reel stop in case of parted pipe on surface
- Automatic emergency brake actuation on detection of reel drive chain failure
- Hydraulic filter condition monitoring
- Automatic engine shutdown on engine failure
- Up to 4 camera video display
- Pan-tilt-zoom camera available
- Potential for wireless connection from unit to control console



Figure 8 – OpsCab\* Controls

The drilling controls will use the OpsCab\* architecture as the basis for design. Currently we are evaluating use of the OpsCab\* computer with a new program to control the drilling operations. By reusing the OpsCab\* computer we can also reuse the enclosure and only make slight modifications to the controls mounted on the enclosure.

The drilling control panel will be capable of controlling the following drilling functions.

- Drawworks
- Mud pumps
- Catwalk trailer
- Choke manifold
- Valves between active pits and reserve pits
- Slips
- Tongs
- Power Swivel or Top Drive

The data acquisition system will be used to generate and automatically update the drillers report. A key driver behind incorporating this feature is to allow the driller to easily complete a more accurate and complete report of the drilling process. The following is a list of items that we would like to incorporate into the drilling report.

- Time and Date
- Depth
- Fluid rates
- Pressures (Wellhead, Choke, Pump)
- Pit Volumes
- Mud Density
- Coiled Tubing Weight/ Calculated effective weight on bit

- Rotary Weight on Bit

By recording this data and providing a simple input path for entering non recorded data it is hope full that a more complete and comprehensive report of daily activities is kept.

## Business Plan

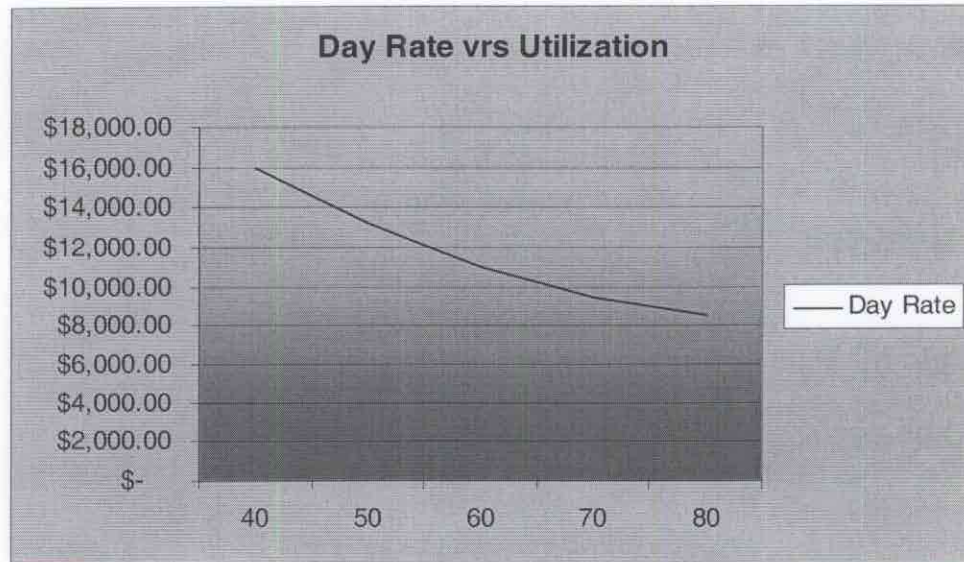
*The purpose of this chapter is to detail how the final MCTR concept will fit into the market and what types of long term opportunities we believe it will offer.*

The layout of the MCTR concept provides for a very flexible package that can be adapted and scaled for many different drilling or work over environments. The problem with a lot of new technologies is not the ability to perform the work, but the ability to maintain consistent work. This can be because the market is over estimated or the cost for the technology limits the market. By creating a flexible scalable coiled tubing drilling package it is hoped that the unit can maintain a level of utilization that will allow its cost to remain low and competitive.

Utilization for the MCTR will be a critical factor for setting an operating cost. With each piece of equipment that is owned there is a fixed cost associated with owning and manning the equipment. Two of the largest costs associated with owning and manning the equipment are depreciation and people. These cost occur regardless if the equipment is working or sitting in the yard. Therefore the more the equipment operates the lower the daily operating cost needs to be to offset the fixed costs.

To make this product successful, key clients need to be established that have the resources to keep the equipment busy until the market becomes accepted and interest grows. Identifying clients early on that have a large drilling programs capable of keeping the MCTR busy will be key to establishing an early competitive price that will make the MCTR an attractive alternative to rotary drilling.

The following graph is used to show how utilization affects the day rate required to obtain an equivalent NPV over the project life. The actual day rates depicted are for explanation purposes and may not reflect the actual day rate for the MCTR.



Based on this graph a clear plan needs to be made to insure that utilization is kept above 60% to stay competitive with rotary rig rates for this particular NPV. This may require a change with respect to how coiled tubing units are typically run and operated. Standard coiled tubing units run with 20% - 40% utilization and thus have a higher cost associated with them.

The actual NPV that needs to be met will be determined by alternative investment NPV rates. This means that the MCTR must offer a higher NPV than other investment opportunities for investment to be economically viable.

In order to create the greatest opportunity for higher utilization the MCTR must be able to capitalize on as much of the shallow drilling market as possible. This means that it must be capable of drilling microholes, slimholes and performing re-drills efficiently. Each different drilling operation brings slightly different challenges that the MCTR must address if it is to be able to perform in these markets.

To perform in the microhole market the MCTR must operate at a low cost. It is possible that many of the wells drilled will be for monitoring and exploration purposes only, which means that the well will not directly cover the drilling cost with future production. Therefore the cost must be kept low to minimize the financial risk and increase the value to the client. As the overall cost of the unit will be comparable to the cost of a rotary drilling rig of equal size the main cost savings will need to be made up in reduced location preparation costs, completion cost and man power. The MCTR addresses these issues by a reduced footprint, smaller completion size and the ability to operate with a four-man crew.

The main advantage the MCTR will have for slimhole operations is the ability to mobilize quickly. One key feature that makes the MCTR quick to mobilize is the fact

that parts of the system can be rigged down and prepared for transport prior to final completion of the well. For instance while the production string is being run the coiled tubing unit can be packaged for transport and once the production string is run the mast unit can start to be rigged down for transport. By the time cement is set most of the equipment should be rigged down and ready for transport to the next location.

Coiled tubing drilling rigs in Canada are currently able to complete a well in a day and have mobilization times as low as four hours. It is the equipment's ability to efficiently drill and mobilize compared to rotary drilling rigs that is making coiled tubing drilling so popular in Canada right now. It is hopeful that by keeping the MCTR US DOT road legal we can capitalize on the success being experienced in the Canadian market here in the United States.

The final application that the MCTR will be used for is re-drill applications. Most re-drill applications involve either a sidetrack or hole deepening activities, which may mean going deeper than 5,000 ft. To accommodate the ability to go deeper the coiled tubing drilling unit will be designed to hold a larger reel size capable of holding enough coiled tubing for these deeper operations. Currently 11,000 ft of 2-3/8" coiled tubing is the targeted length of pipe needed for some of the deeper re-drill opportunities.

The drill floor height of the MCTR is also high enough to allow the rig-up over existing wellheads.

Besides the obvious requirements of allowing the coiled tubing drilling unit to efficiently rig-up and deploy long BHAs, the MCTR will also allow existing completions to be pulled with the same unit. Typically coiled tubing re-drill operations require a workover rig to be mobilized first to pull the production tubing and prep the well for coiled tubing. With the MCTR, all of the preparation work can be performed without mobilizing a workover rig.

### **Drilling Evaluation:**

Evaluation of the of the operational efficiency of the new concept will be critical in being able to market the unit as a efficient alternative to conventional drilling methods. In order to perform an accurate comparison, the unit must be compared with a rig performing comparable work in the same area. Pairing up with an operator that will provide the comparative data or that will work with us in collecting the data is critical to getting an accurate comparison.

One of the best methods to perform this analysis is called a task analysis. A task analysis breaks out time by activity and shows where multi-tasking is taking place on an operation. The task analysis allows two similar operations to be compared by task to determine where inefficiencies may exist. The key to performing a task analysis is the ability to observe multiple operations such that a base line or level of consistency is

observed. The baseline operational time breakdowns should be used to compare the different operations.

The task analysis, besides showing one operation as being more efficient than another, can also indicate how certain tasks may be improved such that the overall efficiency is optimized.

It will be important that the new equipment is operated for a long enough period that the crews become completely familiar with the operation before it is compared with an efficient ongoing rotary drilling operation. By doing this we can gain greater data accuracy without extrapolating for crew inefficiencies. The time that the equipment must operate before the crews become proficient will be dictated by the level of activity that the equipment receives.

### **Develop Integrated Package:**

It is important that all of the peripheral support equipment is identified and integrated into the MCTR. The integration of peripheral equipment will help insure that the entire package is assembled efficiently and meets all of the operational requirements. Some of the peripheral support equipment includes but is not limited to the mud system, pumps, generator system, tool room, water tanks and choke manifold system.

The integration of peripheral equipment will take place simultaneously with the design of the MCTR unit and will be completed during the test phase and initial operation of the MCTR.

After the unit is operated for a significant period based on activity level, a report should be generated to identify areas in which the integration of peripheral equipment can be improved or changed to further optimize operations.

### **Personal Training:**

Personnel will need to be trained on the operation of the MCTR and the operation of all peripheral equipment before the equipment is ever used on an actual wellsite. The two main goals with personal training is training enough personnel to support the operation and qualifying the personnel for the operation using a structured competency assurance program.

Based on the results of this introductory training, personalized training can be used to supplement and speed up the competency assurance program to ensure that the equipment is safely operating in the field as soon as possible. To support long term operations and speed technology transfer, on-line training will be created if the equipment becomes fully commercialized.

An operations manual and maintenance manual will be created to support and help train new operators before the MCTR is released to the field. This is critical to insure that the equipment is operated and maintained properly in the field.

**Business Model:**

Based on our initial test results of the MCTR, it will be the job of our Marketing department to develop a detailed business model to determine how best to introduce the MCTR to the market place and how we will support it internally to help grow the market.

The business model should include price structure for the unit, personnel support structure, growth plan, marketing strategy and value analysis.